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Safe Lifting in Patients with Chronic Low Back Pain: Comparing FCE Lifting Task and Niosh Lifting Guideline

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Introduction: *Both the floor-to-waist lifting task of the Isernhagen Work Systems Functional Capacity Evaluation (IWS FCE) and recommended weight limit (RWL) of the NIOSH produce safe lifting weights and are used world-wide nowadays. It is unknown whether they produce similar safe lifting weights. Aim of this study was to compare FCE performance on the floor-to-waist lifting task and RWL of the NIOSH lifting guideline for this task, in patients with chronic low back pain (CLBP).* **Methods**: *Ninety-two patients performed the FCE lifting task. RWL was calculated for this task. Performance was compared with RWL. A lifting index was calculated by dividing performance by RWL. Differences between groups with a lifting index* ≤ 1*, 1–3, and* >3 *were calculated for pain intensity, scores on the Roland Morris Disability Questionnaire (RMDQ) and work status.* **Results**: *Men lifted on average 32.5 kg (SD 15.4) and women 18.8 kg (SD 7.8). RWL for this task was 12.8 kg. Mean difference between performance and RWL was 15.0 kg (SD 14.7; range* -8.8 *to 59.2). The Roland Morris Disability score of patients with a lifting index* ≤ 1 *was significantly lower than patients with a lifting index 1–3 and* >3*. No difference in pain intensity and work status was found between groups.* **Conclusion**: *It was concluded that performance on the FCE floor-to-waist lifting task and RWL of the NIOSH for this task produce different safe lifting weights in individual patients with CLBP, which may result in contradictory recommendations about need for rehabilitation and return to work.*

KEY WORDS: chronic low back pain; functional capacity evaluation; lift ability; work disability; validity.

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INTRODUCTION

Since lifting is a major risk factor for the onset of low back pain (LBP) and sickness absence due to LBP (1–3), several instruments have been developed to determine safe lifting weight limits and to determine a workers' ability to perform a specific lifting task safely (4). The floor-to-waist lifting task from the Isernhagen Functional Capacity Evaluation (IWS FCE) (5), is a performance task frequently used in rehabilitation medicine, which determines safe lifting performance in a laboratory situation in individual patients. The American National Institute for Occupational Safety and Health (NIOSH) developed an equation, to calculate a recommended weight limit (RWL) and a lifting index (LI) in a specific occupational setting (6). A higher LI indicates a higher physical strain for a specific lifting task and thus potentially more harmful for the lower back. Although both instruments were designed for different purposes, the FCE for determining the ability of an individual to perform a certain job with known physical requirements and the RWL of the NIOSH to advice if a job created potential hazard to the worker, both instruments are used world-wide nowadays to determine a workers' ability to perform a specific (job) lifting task safely (7–10).

Instruments for decision-making should be reliable and valid. Reliability refers to the amount of error inherent in any measurement (11). Validity of an instrument refers to what extent the instrument measures what it intends to measure (11). One of the most practical and objective ways to determine validity is to assess the criterion-related validity (12). Criterion validity is usually divided into concurrent and predictive validity, in which concurrent validity refers to the relation with another instrument given at the same time, whereas predictive validity refers to the prediction of a certain outcome in the future (12).

The floor-to-waist lifting task of the IWS FCE has proven good reliability in patients with chronic low back pain (CLBP), with Intra Class Correlations ranging from 0.78 to 0.87 (13–15). Concurrent validity between the FCE lifting task and lifting related questions on the Quebec and Oswestry questionnaire showed poor to moderate relationships (Oswestry 3, $\rho = -0.20$, non-significant; Quebec 20, $r = -0.51$, $p < 0.01$ (16). No significant relation was found between the FCE lifting task and pain intensity (17). The predictive validity for return to work (RTW) of the floor-to-waist lifting task of the IWS FCE is weak. Previous studies showed time off work to be the most important predictor for RTW, with the floor-to-waist lift making only modest contributions (18–22). Additionally, performance on this lifting task was not related to future recurrence of LBP (19,21).

The NIOSH lifting equation is a calculation of RWL, and therefore reliable in its use. Whether the assessment of the lifting task characteristics is reliable, that means the variables in the equation, is unknown. A concurrent validity study of the NIOSH lifting guideline found differences between performance on different lifting tasks and RWL for these tasks in healthy volunteers (23). With respect to predictive validity, a higher LI was associated with higher prevalence of LBP (Odds ratios ranging between 1.00 to 4.6.) (9,10) No studies are available regarding predictive validity of the NIOSH lifting guideline for RTW.

It is not clear whether both instruments determine similar or different recommendations of safe lifting weights, because both instruments have not been concurrently validated. Aim of this study is to determine concurrent validity of the FCE performance on the floor-to-waist lifting task and the calculated RWL of the NIOSH lifting guideline for this task in patients

with CLBP. To explain possible differences between FCE and NIOSH recommendations, a lifting index will be calculated and differences in pain intensity score on the Roland Morris Disability Questionnaire and work status between the different lifting indices will be analyzed.

METHODS

Participants

Ninety-two patients with non-specific CLBP (60 men, 32 women) referred for multidisciplinary rehabilitation treatment in the Center for Rehabilitation, University Medical Center Groningen, the Netherlands, participated in this study. This study was part of a larger study program, LOBADIS (Low Back Pain and Disability), to determine the usefulness of different instruments to measure disability in patients with CLBP. The full procedure of this study has been described elsewhere (24). The participating patients perceived recurrent back problems for years, or had a new episode of LBP of at least three months' duration. All patients signed informed consent. Inclusion criteria were between 18–65 years of age, currently at work, or less than 1 year off work due to CLBP. Exclusion criteria were CLBP with an underlying specific cause, cardiovascular or pulmonary diseases, hypertension, pregnancy, drug addiction and psychopathology. Patients characteristics are shown in Table I.

Instruments

IWS FCE

As part of the IWS FCE, the floor-to-waist lifting task was used to measure maximum lifting performance. Subjects lowered a starting weight from a shelf to the floor, turning 90°

Table I. Patient Characteristics

Variable	Percentage	*n*
Gender		
Men	65	(60)
Women	35	(32)
Recurrence of low back pain	71	(54)
Work status[a]		
Completely at work	31	(27)
Working with restrictions	35	(31)
Completely off work	34	(30)
	Mean	(SD)
Age (years)	38.5	(8.7)
Duration of low back pain (weeks)	75	(24–156)[b]
RMDQ[c]	12.5	(4.8)
Pain intensity score (VAS 100 mm)[d]	48.4	(22.2)

[a] Of four patients, work status was unknown.
[b] Due to a skewed distribution, median and interquartile range are presented.
[c] RMDQ = Score on the Roland Morris Disability Questionnaire, assessing self-reported limitations in ADL, ranging from 0 (no limitations) to 24 (severe limitations).
[d] VAS = Visual Analogue Scale.

and immediately lifted it back, for a set of five repetitions within 90 s. Patients were allowed to pivot their feet. After each set heart rate was monitored, and an additional weight was added. Maximum performance was reached in 4–6 lift sets. Maximum lifting performance was determined when up to acceptable heart rate (85% of age related-maximum) was reached, patient wished to stop, or the observer determined that safety was no longer guaranteed. Two modifications were made from the original protocol (5). First, shelf height at the beginning of the task was set at 74 cm instead of at hip height, and second, patients were tested once, on a single day instead of using a two-day protocol, because the test results on the second day only marginally differed from those on the first day (15).

NIOSH Lifting Equation

The NIOSH lifting equation was used to calculate a RWL, and a LI as a measure of physical strain on the FCE lifting task (6). The RWL is the product of six variables and a constant term, in an equation:

$$\text{RWL} = \text{LC} \times \text{HM} \times \text{VM} \times \text{DM} \times \text{AM} \times \text{FM} \times \text{CM}$$

Where LC = Load Constant (23 kg), HM = Horizontal Multiplier, VM = Vertical Multiplier, DM = Distance Multiplier, AM = Asymmetric Multiplier, FM = Frequency Multiplier, CM = Coupling Multiplier (6). Operational definitions of the multipliers are presented in the appendix. RWL was calculated at the beginning and at the end of the lifting task. In the FCE lifting task, patients held the weight close to their body ($H < 25$). The absolute vertical travel distance of the weight was 74 cm (V). Because patients were allowed to pivot their feet, the angle of asymmetry (A) was 0 degrees both at the beginning and end of the lifting task. The NIOSH lifting equation assumes that lifting and lowering have the same risk for LBP (6, 25). Because both lifting and lowering occurs in the FCE lifting task, one set of five repetitions includes 10 lifts within 90 s (= maximum 6.7 lifts per minute, [F]). Coupling (C) of the box was good, box height was 26 cm with cut-out handles 3 cm below box height. The RWL of the FCE lifting task was determined by calculating the six multipliers and filling in the equation. LC, HM, DM, FM, AM, and CM remain constant at the beginning and end of the lifting task. VM differs at the beginning and end of the lifting task and was calculated separately. Because all patients performed the same floor-to-waist lifting task, RWL was a constant for all patients. The LI is the maximal performance on the FCE lifting task divided by RWL. The lowest RWL should be used in calculating LI (worst case) (6).

Potential Confounders

To explain possible differences between FCE and NIOSH recommendations, pain intensity, self-reported limitations in activities in daily living (ADL) and work status were assessed. A 10 cm Visual Analogue Scale (VAS) was used to assess current pain intensity, ranging from no pain [0] to unbearable pain [10] (26). The reliability and validity of the scale is good (27,28). The Dutch language version of the Roland Morris Disability Questionnaire (RMDQ-Dv) was used to measure self-reported limitations in ADL. The questionnaire has proven good reliability and responsiveness in patients with CLBP (29–34). Work status was defined as completely at work, working with restrictions associated with LBP (e.g. reduced hours, slower pace, less heavy work, not regular job) or completely off work associated with LBP.

Table II. Calculation of NIOSH Multipliers for the FCE Lifting Task

Multiplier[a]	Formula	FCE parameter	Value
Load constant (LC)	23 kg	23 kg	23
Horizontal (HM)	25/H	$H \leq 25$	1
Vertical (VM)	$1 - (0.003 \times \lvert V - 75 \rvert)$	$V_{beginning} = 97$ cm	0.934
		$V_{end} = 23$ cm	0.844
Distance (DM)	$0.82 + (4.5/D)$	$D = 74$ cm	0.88
Asymmetry (AM)	$1 - (0.0032A)$	$A = 0^{\circ}$	1
Frequency (FM)	From tables[a]	6.7 lifts/min	0.735
Coupling (CM)	From tables[a]	Good	1

[a]Operational definitions and tables of NIOSH Multipliers are presented in the appendix.

Statistical Analysis

Mean difference between FCE performance and RWL was calculated. LI was calculated using the lowest RWL. Men and women were analyzed separately, because of differences in lifting capacity. Additionally, patients were divided into three groups: $0<LI=1$; $1<LI=3$; $LI>3$. To analyze differences between the groups, ANOVA was applied with respect to pain intensity and RMDQ-score, with Bonferroni post-hoc analysis for multiple comparisons. Chi-square test was applied with respect work status. Differences were judged as significant when $p \leq 0.05$.

RESULTS

RWL for the FCE lifting task was 12.8 kg at the end of the task (worst case, calculation values given in Table II). Men lifted on average 32.5 kg (SD 15.4) and women 18.8 kg (SD 7.8). Mean difference between FCE performance and RWL was 15.0 kg (SD 14.7, range − 8.8 to 59.2). In total, 87% of all male patients ($n = 52$) and 75% of all female patients ($n = 24$) had a $LI>1$ and 33% of all male patients ($n = 20$) and 3% of all female patients ($n = 1$) had a $LI > 3$.

Table III. Differences in Pain Intensity and Work Status for Different Lifting Indices (LI)

	$0<LI \leq 1$	$1<LI \leq 3$	$LI>3$	*p*-value
Percentage (*n*)	17 (16)	60 (55)	23 (21)	
Work status[a] (% [n])				0.06
Working	33 (5)	31 (16)	29 (6)	
Working with restrictions	20 (3)	46 (24)	19 (4)	
Completely off work	47 (7)	23 (12)	52 (11)	
Pain intensity score (VAS 100 mm)[b]	49.6 (20.1)	48.1 (22.0)	48.2 (26.0)	0.98
RMDQ-score[b,c]	15.8 (3.2)	12.0 (4.7)	11.5 (5.4)	0.02

[a]Of four patients, work status was unknown.
[b]VAS = Visual Analogue Scale. Results presented in mean (SD).
[c]RMDQ = Score on the Roland Morris Disability Questionnaire, assessing self-reported limitations in ADL, ranging from 0 (no limitations) to 24 (severe limitations). Post-hoc analysis showed significant differences between patients with $0<LI=1$ and $1<LI=3$ ($p = 0.03$) and between patients with $0<LI = 1$ and $LI>3$ ($p = 0.03$).

No significant differences were found in pain intensity between the LI groups. Significant differences were found between the groups and RMDQ-score. Patients with $0<LI=1$ had a higher RMDQ score than patients with $1<LI=3$ ($p=0.03$) and than patients with $LI>3$ ($p=0.03$). No significant linear relation was found between work status and the LI groups ($p=0.06$). However, the majority of the patients with $LI>3$ were restricted in work (Table III).

DISCUSSION

When using the FCE performance on the floor-to-waist lifting task or the RWL of the NIOSH for this task, discrepancies in recommended safe lifting weights would be on average 15.0 kg. In most cases, the FCE lifting task recommends a higher safe lifting weight than the RWL of the NIOSH. Therefore, it is possible that after rehabilitation, a patient with CLBP is able to perform a specific lifting task safely as assessed by using the FCE, but once back at the workplace, using NIOSH guidelines, it can be recommended that the lifting task should be adjusted or the worker should be trained. These differences between the two instruments may lead to contradictory recommendations about need for rehabilitation or RTW.

Because lack of a gold standard to estimate the safe weight, it is unclear which instrument estimates the correct safe weight. This study showed that 87% of all male patients and 75% of all female patients were able to lift the RWL of the NIOSH on the FCE lifting task. Therefore, RWL seems to be an acceptable safe weight in 87% of all male patients and 75% of all female patients. According to NIOSH, the percentage of healthy persons for whom the RWL is an acceptable safe weight is respectively 99 and 75% for male and female workers (6). Thirty-three percent of all male patients and 3% of all female patients in this study were able to lift a weight which is at least three times higher than RWL, against 25% and 1% of healthy male and female workers according to NIOSH (6). Male patients in this study performed a little less than is acceptable according to NIOSH for healthy males. Female patients performed similar to what is acceptable according to NIOSH for healthy females. These results show that in groups of patients, lifting performance is about to be similar to that of industry design standards for groups of healthy persons.

According to NIOSH, performing above RWL on the FCE lifting task ($LI>1$) means that most patients are considered at risk for back injury and absenteeism during this task. However, in this study, no significant relation was found between LI and pain intensity or LI and work restrictions. In addition, patients who were able to lift the RWL of the NIOSH, had a lower RMDQ score. These results seem contrary to the hypothesis that a higher LI is more harmful for the lower back. A previous study on 13 healthy volunteers also showed that the maximum performance on a lifting task was higher than the RWL calculated for that task, with LIs ranging between 2.5 to 5.3 (23). Additionally, another study showed that the revised NIOSH lifting equation overestimated the number of high risk jobs for LBP (9). Therefore, it is concluded that application of the NIOSH guideline in clinical decision making or RTW recommendations in individual patients with CLBP may result in an under-estimation of safe lifting weight limits, which may lead to work-restrictions and costs that may not be necessary.

Use of the floor-to-waist lifting task of the IWS FCE for recommendations about safe lifting weights and about need for rehabilitation and RTW is also limited. The

floor-to-waist lifting task is performed in 5–10 min. The performance on this task is assumed to be representative for lifting occasionally (i.e., 1–5% of a working day.) (5) However, the translation from 5 to 10 min lifting to lifting occasionally has not been validated. Additionally, according to the IWS FCE, the load should be multiplied with 1/4 to estimate a safe weight during an 8-hour working day. This translation has also never been validated, and is not comparable with the frequency multiplier of the NIOSH. In our study, the frequency multiplier (FM) was 0.735. This was for lifting <1 hour (see Table A.1 in appendix), which means a reduction factor of approximately 1/3. When translating both tasks to an 8-h working day, the FCE lifting task has a higher reduction of weight (multiply with 1/3 instead of 1/4). Therefore, recommendations of the IWS FCE and the NIOSH over an 8-h working day will be more similar than for lifting occasionally. Although the floor-to waist lift of the IWS FCE is a performance test, which objectively and reliably assesses functional limitations in lifting tasks in patients with CLBP (13–15), it has also weak validity for RTW or recurrence of symptoms, and a substantial natural variation, which means that differences in test results within individual patients are large (13,18–22). This should be taken into account when using this task in recommendations about need for rehabilitation and RTW in individual patients.

No linear relationship between LI and work status was found. Remarkably, patients who performed three times higher than recommended by NIOSH (LI>3), were in majority restricted in work. This may indicate the existence of a subgroup of patients that tend to overexert themselves. This finding appears consistent with literature and observations in clinical practice, that there is a group of patients characterized by an overactive lifestyle, perfectionism and negative emotions (35,36), and who underestimate pain (37,38). These patients tend to have large fluctuations in physical activity levels over time (39). It is hypothesized that over-activity periods result in persistence of pain and related restrictions in work in patients with CLBP. Future research should investigate this hypothesis in patients with CLBP.

Limitations of this study consider the accuracy of calculating RWL for the IWS FCE lifting task. During the study, the horizontal location was not controlled. Some patients may have held the load more than 25 cm from their body. Additionally, patients were able to pivot their feet, thus asymmetry was set at 0°. However, the angle of asymmetry was not controlled for in this study. Patients lifted 1 set of repetitions on average easily within 90 s. Therefore, lifting frequency ranged in practice between 6.7 and 10 min. Applying a horizontal location more than 25 cm, an angle of asymmetry more than 0° and a higher lifting frequency results in a lower RWL. Additionally, patients may not have performed to their physical maximum. A lower RWL or a higher performance makes the difference between FCE test results and RWL even larger. Therefore, these limitations would not result in different conclusions of this study. The calculation of the frequency multiplier could not be made accurately, because NIOSH only generates multipliers for a lifting duration less than one hour. The FCE lifting task however, was performed once, in about 5–10 min, which is a more specific time range than less than one hour. Although a previous study showed that lifting frequency did not significantly contribute to the prediction of high risk jobs (9), a change in lifting frequency seems to be the most restrictive factor in RWL calculations (also see Table A.1 on FM in appendix) (23). Therefore, to what extent the FM adjusted for lifting 5–10 min instead of less than one hour would alter RWL is unknown and should be addressed in future research. It should be mentioned that results presented in this

Table A.1. Frequency Factor (Ff)[6]

	Duration of lifting performance					
	≤ 8 h		≤ 2 h		≤ 1 h	
Lifts/min	V<75	V ≥ 75	V<75	V ≥ 75	V<75	V ≥ 75
0.2	0.85	0.85	0.95	0.95	1.00	1.00
0.5	0.81	0.81	0.92	0.92	0.97	0.97
1	0.75	0.75	0.88	0.88	0.94	0.94
2	0.65	0.65	0.84	0.84	0.91	0.91
3	0.55	0.55	0.79	0.79	0.88	0.88
4	0.45	0.45	0.72	0.72	0.84	0.84
5	0.35	0.35	0.60	0.60	0.80	0.80
6	0.27	0.27	0.50	0.50	0.75	0.75
7	0.22	0.22	0.42	0.42	0.70	0.70
8	0.18	0.18	0.35	0.35	0.60	0.60
9	0.00	0.15	0.30	0.30	0.52	0.52
10	0.00	0.13	0.26	0.26	0.45	0.45
11	0.00	0.00	0.00	0.23	0.41	0.41
12	0.00	0.00	0.00	0.21	0.37	0.37
13	0.00	0.00	0.00	0.00	0.00	0.34
14	0.00	0.00	0.00	0.00	0.00	0.31
15	0.00	0.00	0.00	0.00	0.00	0.28
15	0.00	0.00	0.00	0.00	0.00	0.00

Note. V = Vertical location, defined as the vertical height of the hands above the floor (cm).

study are only applicable to the IWS FCE. In this study, statistical methods to determine concurrent validity were limited by comparing test results and a calculated RWL. Because the RWL exists of 1 recommendation, calculation of a correlation coefficient was not possible.

It can be concluded that performance on the IWS FCE floor-to-waist lifting task and the RWL of the NIOSH for this task do not produce similar safe lifting weights. Therefore, despite of a reliable assessment, use of these instruments in individual patients can result in contradictory recommendations about need for rehabilitation and RTW. Both the IWS FCE floor-to-waist lifting task and the RWL of the NIOSH should be further validated to answer the question which safe lifting recommendation is actually "safe."

APPENDIX

NIOSH Guideline

RWL should be calculated at the beginning and at the end of an lifting task. The lowest RWL should be used in calculating LI (worst case).

$$\mathrm{RWL} = \mathrm{LC} \times \mathrm{HM} \times \mathrm{VM} \times \mathrm{DM} \times \mathrm{AM} \times \mathrm{FM} \times \mathrm{CM}$$

RWL = recommended weight limit; LC = Load constant = 23 kg; HM = Horizontal Multiplier = 25/H in which H = horizontal location, measured from the mid-point of the line joining the inner ankle bones to a point projected on the floor directly below the mid-point of the hand grasps (cm). VM = Vertical Multiplier = $1 - (0.003|\mathrm{V} - 75|)$ in which

Table A.2. Coupling Factor (Cf)[6]

Coupling	V<75	V ≥ 75
Good	1.00	1.00
Normal	0.95	1.00
Bad	0.90	0.90

Note. V = Vertical location, defined as the vertical height of the hands above the floor (cm).

V = vertical location, defined as the vertical height of the hands above the floor (cm). DM = Distance Multiplier = 0.82 + (4.5/D) in which D = absolute vertical travel distance, defined as the vertical travel distance of the hands between the origin and destination of the lift (cm). AM = Asymmetric Multiplier = 1 − (0.0032A) in which A is the asymmetry angle, defined as the angle between the asymmetry line and the mid-sagittal line (degrees). FM = Frequency Multiplier = From Table A.1, defined by a) the number of lifts per minute (frequency), b) the amount of time engaged in the lifting activity (duration) and c) the vertical height of the lift from the floor. CM = Coupling Multiplier = From Table A.2, based on the coupling classification (good, fair, poor) and the vertical location of the lift.

$$LI = L/RWL$$

LI = Lifting Index, which provide a relative estimate of the physical stress associated with the manual lifting task; L = Load Weight = weight of the object lifted (kg). In this study, L = the maximal performance on the FCE lifting task.

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